

Chapter 3: Heating System Measures

3.1 Heating Systems

This chapter covers improvements to heating systems. The improvements include the replacement or the modification and repair of the appliance. Complete combustion safety testing for all systems and steady-state efficiency (SSE) testing on gas and oil heating systems. All heating system work shall be completed by qualified professionals.

3.2 General Heating System Replacement

All replacement heating systems, except for wood space heaters, shall meet the minimum efficiency standards as specified in the Wisconsin Weatherization Program Manual and listed in the AHRI Directory of Certified Product Performance. Wood heater installation shall conform to the requirement of NFPA 211. Observe the following standards for heating system replacement:

1. Disconnect refrigerant lines, plumbing, ducts, electric, control wires, vents, and fuel supply, when applicable.
2. Install heating systems in accordance with manufacturer's instructions and applicable state and local codes.
3. Use existing distribution system and fuel supply line, when possible.
4. Properly remove and dispose of existing unit.
5. Provide an owner's manual with heating system replacements on or near the heating system. The manual shall be attached in a durable device that allows for repeated customer access.
6. Properly size replacement heating systems units using an accurate analysis through REScheck, ACCA Manual J, or an equivalent industry-accepted sizing procedure.
 - a. When sizing boiler systems, consider the capacity of the existing terminal devices and whether or not domestic hot water will be heated with the boiler.
7. Install gas pipe that is supported and electrically bonded (if required) in accordance with NFPA-54 and the WI Uniform Dwelling Code. Follow the manufacturer's specifications for installation. For more information see NFPA-54 and WI SPS 323.16.
 - a. When CSST is already present in the building and not correctly bonded, bond the gas piping system to the electrical ground in accordance with NEC 250.94 and 250.104.
8. New heating systems require a dedicated electrical circuit rated or fused to match the amperage of the system's requirements for overcurrent protection. Condensate pumps are allowed to be on the same circuit.

9. Verify and make adjustments, if necessary, so flue-gas oxygen, stack temperature, and carbon-monoxide levels are within manufacturer's specifications. If manufacturer's specifications are not available, refer to *Table 3-2* or *Table 3-5*.
10. Install condensate tubing or piping to reach an appropriate drain. Utilize a hose protection ramp (trip strip) instead of a condensate pump where feasible.
11. Install a condensate pump when the condensate tubing will not drain adequately to an appropriate drain or may cause a tripping hazard. See *Condensate Removal in Chapter 3 – Section 3.8.2* for more information about condensate pumps.
12. Seal openings in chimneys where natural-draft or fan-assisted appliances are eliminated. Indicate with a written notice on the chimney, where sealed, that the chimney is no longer functional.
13. Ensure all remaining naturally-vented combustion appliances are drafting properly.
14. Test the heating system's safety mechanisms to confirm they are operating properly and per the manufacturer's specifications (e.g., blower compartment's safety switch and emergency heat circuit are functioning, etc.).
15. Provide in-home operation and maintenance instructions, including a review of safety precautions to the customer.
16. Affix a tag, displayed prominently, identifying who the customer should call for service to the heating unit. The tag information shall contain the name, address, and telephone number of the service organization as well as the date of installation.
17. WHEN A HEATING SYSTEM IS LOCATED IN A CRAWL SPACE: Complete and inspect all heating system work before performing any other measures in the crawl space.

3.3 Forced-Air Furnace Replacement

Observe the following standards specific to forced-air furnace installation:

1. Set fan speed and fuel input for optimal occupant comfort within the manufacturer's temperature rise limits.
2. Perform all required tests and document results.
3. Seal holes through the jacket of the air handler with mastic or foil tape that is UL181 listed.

3.4 Forced-Air Furnace Air Distribution

Forced-air duct systems present opportunities for saving energy in homes. Ducts waste energy through air leaks, lack of insulation, and airflow problems when they pass through unconditioned spaces. This section addresses these forced-air distribution problems.

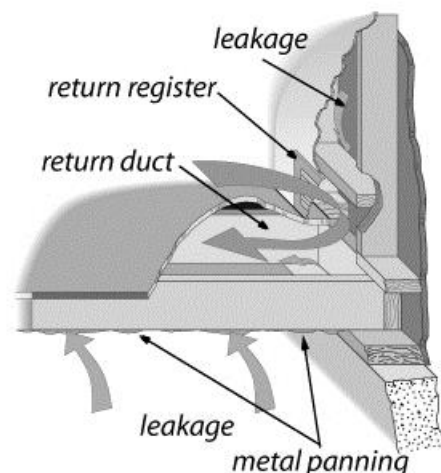
3.4.1 Duct System Modification

If adjusting the fan speed and other minor improvements do not bring the temperature rise within manufactures specifications, duct work modifications may be considered.

Ductwork runs installed to provide heat to individual spaces shall be as short as possible. The placement of a register shall be where it is least likely to be blocked by furniture or other obstacles.

If possible, a single return air grill shall be provided with the shortest ductwork run possible to a central location on the main floor that is heated. If another floor is heated that can be closed off from the main floor, an additional return air grill may be installed with the shortest ductwork run possible to a central location. This may not apply to a basement when back-drafting or other health and safety risks or efficiency issues are present.

1. Design new ducts in accordance with ANSI/ACCA Manual D and manufacturer's specifications.
2. Design terminations in accordance with ANSI/ACCA Manual T and manufacturer's instruction.
3. Do not add supply registers to the combustion-appliance zone (CAZ) unless it is an intentionally heated space. Consult with the customer about removing existing grills in the CAZ. If grills are removed, document the customer consultation in the file.
4. Mechanically fasten supply and return ductwork with screws. Seal the ductwork to the furnace cabinet with mastic and fabric mesh tape, caulk, or other UL 181-approved material, to form an essentially airtight connection on all sides of these joints.
5. Do not install new ductwork in unconditioned spaces unless necessary. If ducts are located in unconditioned spaces, seal the joints and insulate the ducts to a minimum R-11.
6. Connect new ducts to the existing distribution. Install a balancing damper in each new branch supply duct. Install registers to terminate each new supply or return branch duct.
7. Do not use building spaces, like basements or crawl spaces, as a plenum or duct.



Panned floor joints: These return ducts are often very leaky and may require removing the panning to seal the cavity.

3.4.2 Duct Leakage

Leaky ductwork poses two problems: it may affect the occupants' health and safety, comfort, and the home's energy consumption.

Seal all heating and cooling ductwork that runs outside the dwelling's heated envelope. These duct leaks waste energy, and introduce health and safety hazards. For

example, leaky supply ducts can introduce excessive moisture into unheated spaces, and depressurize the home. When return ducts leak in unheated spaces, they may serve to draw pollutants into the distribution stream of air.

In the CAZ, return-ductwork leakage causes depressurization and increases the likelihood natural-draft appliances will backdraft. Supply-side leaks in the CAZ are less likely to cause backdrafts; rather, they may aid the appliances' natural draft by adding positive pressure to the room.

Duct leakage that occurs inside the heated envelope is less likely to contribute to increased energy consumption. The leakage; however, may lead to an unintentional and uneven distribution of heat throughout the home, with less hot air distributing to the rooms where the occupants spend much of their time.

Follow these instructions when sealing ductwork:

1. After completing Steps 2-5, follow the Diagnostic Workbook to guide further sealing.
2. If needed, prepare duct surfaces according to the product manufacturer specifications.
3. Seal all ducts located outside the thermal boundary.
4. Seal the connection between the furnace and the supply plenum, as well as the connection between the furnace and the return drop.
5. Seal all gross holes in the supply and return ductwork.
6. Consider temporarily removing joist panning along the building's exterior, to investigate for air infiltration into the duct system. Replace joist panning when investigation is complete.
7. Flex Ducting: Pull the flex-duct liner up onto the metal duct as far as possible before securing the interior liner of the flex-to-metal connection. Fasten the connection with tie-bands, using a tie-band-tensioning tool or a mechanical band.

Materials for Duct Air Sealing

Duct mastic is the preferred duct-sealing material because of its superior durability and adhesion. Apply mastic at least $\frac{1}{16}$ -inch thick and use reinforcing mesh or UL 181-approved tape for all joints wider than $\frac{1}{8}$ inch or joints that may experience some movement. Silicone or siliconized acrylic-latex caulk is acceptable for sealing wood-to-wood joints in panned joist spaces that function as return ducts.

Joints should rely on mechanical fasteners to prevent joint movement or separation. Tape alone will not hold a joint together, and it will not resist the force of compacted insulation or joint movement. Aluminum foil tape or cloth duct tape are not good materials for duct sealing because their adhesive often fails after a short time.

3.4.3 Duct Insulation

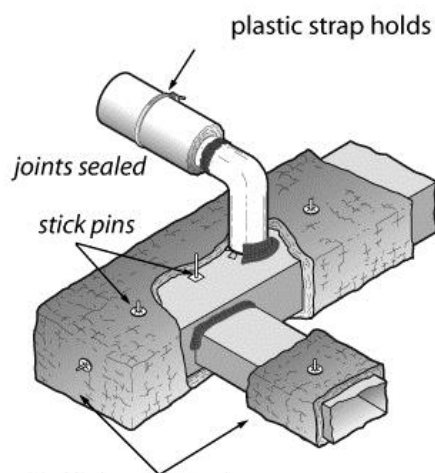
Insulate forced-air ducts that run through unconditioned areas with foil-faced duct insulation with a minimum value of R-11. Ducts may be insulated with two-part foam products that meet the federal specification for duct insulation. If two-part foam is used, workers must ensure all seams are sealed to assure the air stream does not come in contact with the foam.

Do not apply duct insulation to ducts that will be surrounded by R-11 or more of loose-fill insulation. Before installing the loose-fill insulation, make sure to seal these ducts.

Do not insulate ducts that run through conditioned areas unless they cause overheating in winter or condensation in summer.

Follow these steps when installing duct insulation:

1. Perform necessary duct sealing before insulating ducts.
2. Insulate all exposed forced-air ducts in unconditioned areas, so no significant areas of bare duct are left un-insulated.
3. Fasten insulation mechanically, using stick pins, twine, plastic straps, or other appropriate materials. Tape the joints in the insulation to prevent air convection, and apply mastic over the tape to increase the tape's longevity.



R-11 duct insulation fastened with stick pins

Duct insulation: Forced air ducts, located in unheated areas, should be insulated to a minimum of R-11.

3.4.4 Measuring System Airflow

Low airflow is a common problem in forced-air duct systems. Furnace airflow significantly affects the temperature rise. Excessive airflow (low supply air temperature) may cause customer-comfort issues. Insufficient airflow may cause short cycling or, in severe cases, failure of the heat exchanger.

The most common causes are an oversized furnace, a dirty filter, a dirty A-coil, registers or grilles blocked, fuel input too high, fan speed too low/too high, too-small of supply ducts, and inadequate or restricted return ducts. *Table 3.1* shows recommended minimum airflow for various forced air systems. When airflow is lower than the recommended minimum, the system is likely to have a temperature rise that is higher than the maximum specified by the manufacturer.

Table 3-1: Recommended Minimum Airflow (in CFM)

Furnace Size in kBtu	Natural Draft	Fan- Assisted Draft	Sealed Combustion
40	400	520	600
50	500	650	750
60	600	780	900
75	750	975	1,125
100	1,000	1,300	1,500
Multiplier			
kBtu x	10	13	15
To calculate the estimated minimum airflow for a furnace, multiply the input kBtu by the multiplier for the type of furnace. (e.g., 40 x 15 = 600 CFM)			

Preparing to Measure Airflow

Sophisticated test instruments are not necessary to discover that filters, air-conditioning coils (A-coils), or blowers are packed with dirt or the branch duct to the master bedroom is disconnected. Diagnose these problems before measuring duct airflow. The following steps precede airflow measurements:

1. Ask the customer about comfort problems and temperature differences in various parts of the home.
2. Based on the customer's comments, look for disconnected or restricted ducts.
3. Inspect the filter(s), blower fan, and A-coil for dirt. Clean them if necessary. If the A-coil is not easily visible, a dirty blower fan is a fair indicator that the A-coil may also be dirty.

Flow-Plate Method for Measuring System Airflow

The flow-plate meter is a plate with holes and sampling tubes that work in conjunction with a digital manometer to measure the velocity and static pressures inside the ductwork. The manometer then converts these values into an estimate of the distribution airflow.

The flow-plate meter will contain metering plates that can be configured to fit inside all standard-size filter slots. Whenever possible, make sure the plate is not bigger than the return cutout in the furnace. See the instruction manual for the flow-plate meter for specific directions on its use.

Measuring External Static Pressure

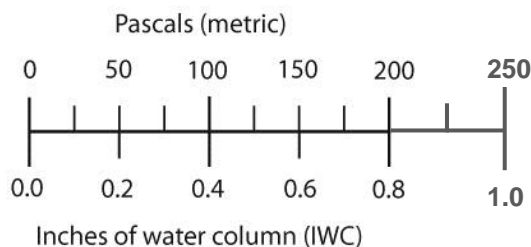
Perform this test if initial temperature rise and CO, as measured tests, are outside of manufactures specifications and additional investigation is needed. External static pressure (ESP) is the difference between pressures in the supply and return ductwork. ESP is the airflow resistance caused by items external to the furnace cabinet. The ESP test can be used to identify existing ductwork issues such as insufficiently sized ductwork or obstructed cold air returns.

Testing for ESP also allows for estimation of airflow if the furnace manufacturer's fan tables for static pressure and airflow are available.

ESP equals the sum of the absolute values of the static pressures in the supply and return sides.

For example, a supply-side static pressure of +30 Pascals and a return-side static pressure of -80 Pascals indicate an ESP of 110 Pascals ($80 + 30 = 110$). The supply-side static pressure will

always be a positive number, and the return-side static pressure will always be a negative number. The larger the ESP, the lower the airflow at a given fan speed.

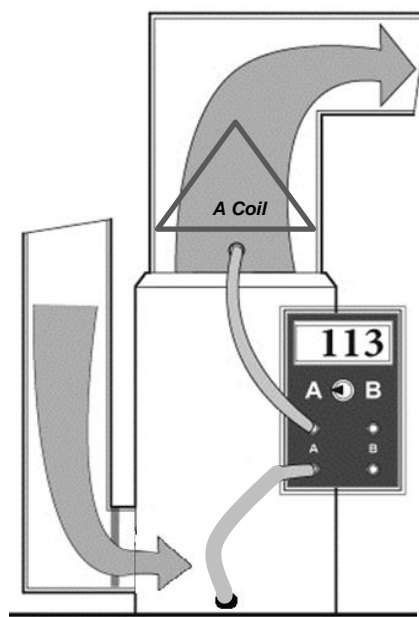


Pressure in two measurement systems:

Technicians and engineers are both Pascals (metric) and inches of water column to measure duct pressures.

The ESP test requires a static-pressure probe, a pressure hose, and a digital manometer. Follow these steps to test the ESP of a forced-air heating system:

1. Install a clean furnace filter into the filter slot. If one is not available, remove the existing furnace filter if it is plugged or excessively dirty.
2. Drill one hole in the supply plenum, above the furnace cabinet and below the A-coil drain pan (if present). The hole must be large enough to accommodate a static-pressure probe. If the A-coil is mounted directly to the furnace, in order not to drill a hole in the coil or drain pan, drill a hole in the very top of the furnace cabinet. Be sure not to drill through a furnace baffle or heat exchanger. Ensure the hole goes through the insulation inside the furnace cabinet.



External static pressure (ESP): The positive and negative pressures created by the resistance of the supply and return ducts produces ESP. The measurement shown here simply adds the two static pressures without regard for their signs. As ESP increases, airflow decreases. Numbers shown here are for example only.

External Static Pressure

ESP (IWC)	0.3	0.4	0.5	0.6	0.7	0.8
CFM	995	945	895	840	760	670

3. Drill one hole into the back of the blower cabinet. The hole must be large enough to accommodate a static-pressure probe. Be sure not to drill into wiring or other objects by removing the blower cabinet door to visually select a location free from obstacles. Ensure the hole goes through the insulation inside the Blower cabinet.

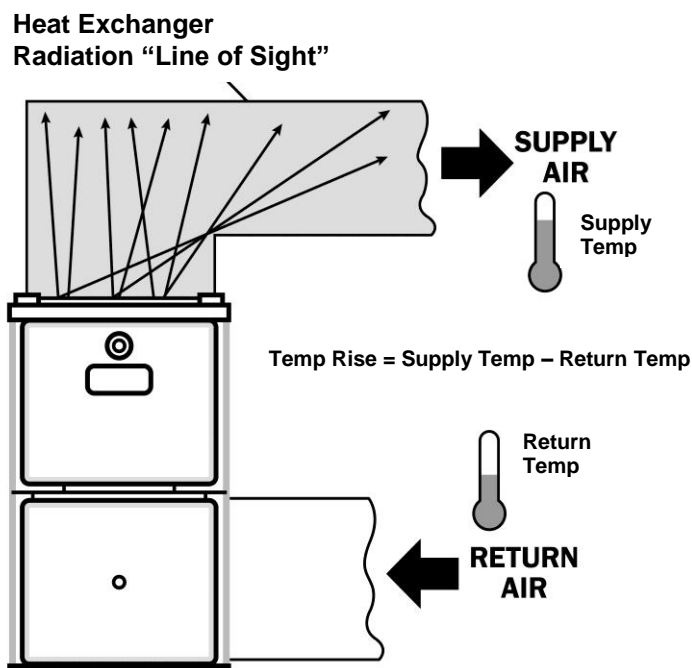
4. Set the digital manometer to “PR/PR” mode, and attach a pressure hose to the Channel A input tap. (The “UNITS” button can be used on the monometer to measure Inches of Water Column).
5. Attach the static-pressure probe to the hose. Insert the probe into each of the holes and record the test result for each hole.
6. Add the absolute values of the two test results, treating each result as if it were a positive number. This sum is the ESP for the heating system.
7. The higher the ESP measurement, the lower the airflow will be (assuming no change in the air handler’s speed setting). The manufacturers’ maximum recommended ESP is usually 0.50 IWC for standard air handlers. As ESP increases above 0.50 IWC, the likelihood of insufficient airflow increases. A very high ESP (over 1.0 IWC) may indicate an oversized furnace, the presence of constricted or insufficient ductwork, a plugged A-coil or furnace filter, or other distribution-system issues.

Use the ESP test as a guide, along with customer conversations and the airflow and temperature-rise tests, in determining whether the heating system has sufficient airflow.

3.4.5 Measuring Temperature Rise

Temperature rise is the temperature difference between the supplied air and the return air. This test is critical in determining if the furnace is set up and operating properly. Perform the test after the furnace has reached steady state and the ductwork has heated up.

Measure the return temperature by inserting the thermometer in the return drop prior to the filter. Measure the supply temperature in a main duct within 6 feet of the supply plenum without being in the line of sight of the heat exchanger. When there are multiple main ducts, measure the temperature in each branch and use the highest reading.



3.4.6 Filters

Observe the following standards related to furnace filter installation.

1. Supply the customer with MERV 6 or higher furnace filters. Provide either:
 - a. Six one- to two-inch replaceable filters (install one of them in the furnace); or

- b. One washable filter (installed); or
 - c. One deep-pleated filter (installed).
2. Confirm filters are held firmly in place and provide complete coverage of the blower intake or the return register.
 3. Ensure filters are easy to replace.
 4. Confirm the heating system has a sealing filter cover, and install a new one if none exists. Construct the new filter-slot cover so it can be removed easily and safely. Confirm the filter is easy to access and replace. Magnetic filter covers are allowed only if they provide an adequate seal to the ductwork to prevent air leakage.

3.5 Boiler Replacement

Complete all tests on the Hot Water Boiler Replacement Check List and document results.

Follow these specifications when replacing boilers:

1. To size a replacement system accurately, consider the home's design-temperature heat loss, the room-by-room heat loss, and also the home's existing radiation capacity. In situations of insufficient radiation capacity, the home may need more heat emitters in order to optimize the new system's efficiency and to heat all rooms adequately.
2. Flush the existing distribution system per manufacturer's instructions or until the water runs clean and is free of sediment. Verify proper pH and sediment values as provided by manufacturer. With a zoned system, flush each zone separately.
3. Install isolation valves at accessible points in the supply- and return-pipe connections and as near to the boiler as is convenient and practical to permit draining the boiler without emptying the system. These valves can also serve for filling the system and purging air from separate zones.
4. Locate new zone valves or zone circulating pumps near the boiler. Confirm each zone has its own shut-off valve.
5. Install a pressure-relief valve (PRV) per manufacturer's instructions. Confirm the PRV is rated and sized correctly for the boiler BTU input and maximum operating pressure.
6. Install an automatic fill valve, if none is present.
7. The feed-water (inlet) side of the pressure-reducing feed valve shall have a backflow preventer, with a shut-off valve installed upstream from the backflow preventer, and the boiler (outlet) side of the pressure-reducing feed valve also shall have a shut-off valve to allow for maintenance or replacement without draining the boiler system.



8. The backflow preventer drain shall face the floor.
9. The system shall have an adequately sized expansion tank on the supply side of the boiler. Install an expansion tank or fill the existing expansion tank and the system to the correct level.
10. Install the circulator pump near the downstream side of the expansion tank to prevent the suction side of the pump from depressurizing the piping.
11. Verify return-water temperature is appropriate:
 - a. For oil boilers, verify return-water temperature is above 150° F.
 - b. For non-condensing gas boilers, verify return-water temperature is above 130° F, to prevent acidic condensation within the boiler.
12. Install piping bypasses, mixing valves, primary-secondary piping, or other strategies as necessary to prevent condensation.
13. For condensing boilers, install condensation-resistant venting with condensation drains designed into the venting system per the manufacturer's specifications.
14. Insulate all pipes on the circulating loop between the boiler and an indirect domestic water heater.
15. When installed on a floor below grade, a new boiler shall be installed above known flood levels and as high as practical to avoid damage in case of flooding.
16. Inspect the chimney for deterioration and correct sizing. Repair and reline the chimney as necessary.
17. With standard-efficiency boilers, install a full-closure electric vent damper where feasible.

3.5.1 High-Efficiency (≥ 90%+) Boilers

High-efficiency boilers often present significant energy-saving opportunities as compared with standard-efficiency boilers. Similar to ≥90% efficient furnaces, high-efficiency boilers cause water vapor in the exhaust gases to condense, which releases extra heat and raises its efficiency potential above 90 percent. (High-efficiency systems are often referred to as “condensing” systems.)

To size a replacement system accurately, consider the home's design-temperature heat loss, the room-by-room heat loss, and also the home's existing radiation capacity. In situations of insufficient radiation capacity, the home may need more heat emitters in order to optimize the new system's efficiency and to heat all rooms adequately.



With a high-efficiency boiler, the return water acts as a coolant for the exhaust gases. The lower the temperature of the return water, the more the exhaust gases cool — which in turn increases the amount of water that condenses out of the exhaust, and thus increases the boiler's efficiency. For this reason, lower return-water temperatures correlate with increased efficiencies.

Outside air temperature sensors are installed with a boiler to allow the boiler controls to sense the actual outside temperature. Outdoor reset is a control function allowing the boiler to adjust the supply-water temperature to the minimum needed to heat the building at a given outside temperature. When the boiler limits its heat output to the dwelling's actual need, the lower return-water temperature increases condensation and increases the boiler's efficiency.



High-efficiency boilers require regular maintenance. Some high-efficiency boilers are especially vulnerable to problems with the distribution water — namely, dirt/debris/sediment/rust in the water and also an improper pH level, both of which can lead to plugged heat exchangers and other issues. Educate customers and make sure they understand the maintenance requirements.

Follow these additional instructions when installing high-efficiency boilers:

1. Verify flue-gas O₂ percent or CO₂ and CO ppm are within the manufacturer's ranges for both high and low fire.
2. Equip the boiler with an outside air temperature sensor installed on a north-facing exterior wall. Determine the outdoor temperature above which the boiler should not operate and set high temperature shutoff to match.
3. Program the modulating boiler's heating curve in line with the dwelling's heat loss, outdoor design temperatures and radiation capacity.
4. Ensure the chemistry of the distribution water meets manufacturer's specifications. Testing may include pH, hardness/total dissolved solids (TDS), or inhibitor treatment.

3.6 Hydronic Distribution Systems

Hydronic distribution systems consist of the supply and return piping, the circulator, expansion tank, air separator, air vents, and heat emitters. A properly designed and installed hydronic distribution system can operate for decades. Many systems; however, have installation flaws or need service.

Boiler piping and controls present many options for zoning, boiler staging, and energy-saving controls. Dividing homes into zones, with separate thermostats, can significantly improve energy efficiency over operating a single zone. Modern hydronic controls can provide hot water for heating to different zones at different times with varying heating loads in the zones.

Follow these instructions for hydronic distribution systems:

1. Inspect radiators. Repair or replace as necessary.
2. Bleed air from radiators and from the entire system.
3. Confirm the distribution system has no leaks.
4. Modify the distribution system as necessary to work properly with the replacement boiler.
5. The system shall have automatic and manual air-bleed valves to eliminate air from all high points in the distribution-piping system.
6. Extend new piping and radiators to conditioned areas, like additions and finished basements currently heated by space heaters.
7. Install thermostatically controlled radiator valves on the major radiators; or zone controls; or outdoor reset and boiler controls to adjust supply-water temperature according to outdoor temperature, if feasible for the boiler system. Modulating pumps on multi-zoned systems may be considered.
8. Insulate all supply piping outside conditioned spaces. For hot-water systems, install 1½-inch fiberglass insulation on all pipes less than or equal to 1½ inches in diameter, and 2 inch fiberglass insulation on all pipes greater than 1½ inches in diameter. For steam systems, install 1½ inch fiberglass insulation on all pipes less than or equal to 1½ inches in diameter, and 3 inch fiberglass insulation on all pipes greater than 1½ inch in diameter.



Zone valves: A separate thermostat controls each zone valve. When a thermostat calls for heat, the boiler fires and the zone valve opens.

3.7 Boiler Efficiency and Maintenance

Boilers can maintain good performance and efficiency for many years if they are regularly maintained and tuned-up. Boiler performance and efficiency improve after effective maintenance and tune-up procedures.

Modern high-efficiency boilers require annual maintenance to achieve optimum performance and life expectancy. For information about boiler installation, see *Boiler Replacement in Chapter 3 - Section 3.5*.

Boiler performance and efficiency deteriorate in more ways than in forced-air furnaces. Specifically these are:

1. Corrosion, scaling, and dirt on the water side of the heat exchanger.

2. Corrosion, dust, and dirt on the fire side of the heat exchanger.
3. Excess air during combustion from air leaks and incorrect fuel-air mixture.
4. Off-cycle air circulation through the firebox and heat exchanger, removing heat from stored water.

Consider the following maintenance and efficiency improvements for both hot water and steam boilers:

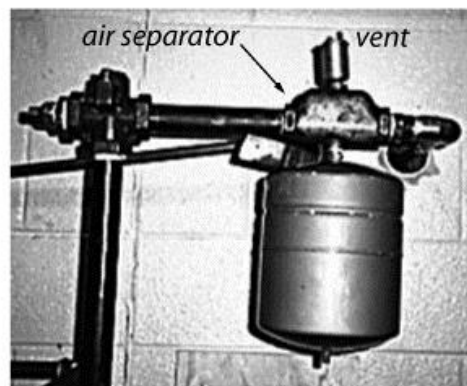
1. Check for leaks on the boiler, around its fittings, or on any of the distribution piping connected to the boiler.
2. On a steam boiler, inspect the water gauge glass for erosion, cracks, or drying. Damaged gauge glass on the boiler should be replaced in accordance with manufacturer specifications. Remove, clean, and replace the gauge glass when dirt or sediment is coating it and making it difficult to observe the water level of the boiler.
3. Clean noticeable dirt from the fireside of the heat exchanger.
4. Check doors and cleanout covers for air leakage. Replace gaskets, warped doors, or warped cleanout covers.
5. Drain water from the boiler drain until the water flows clean.

Safety Checks and Improvements

1. Confirm the existence of a 30 psi-rated pressure-relief valve. Replace a malfunctioning valve or add one if none exists. Note signs of leakage or discharges, and find out why the relief valve is discharging.
2. Make sure the expansion tank is not waterlogged or sized too small for the system. This could cause the pressure-relief valve to discharge. Test expansion tank for acceptable air pressure — usually 12 to 22 psi.

Note: A hot-water boiler is recognized by its expansion tank, located somewhere above the boiler. The expansion tank provides an air cushion to allow the system's water to expand and contract as it is heated and cooled without creating excessive pressure in the boiler piping, and discharging through the pressure-relief valve.

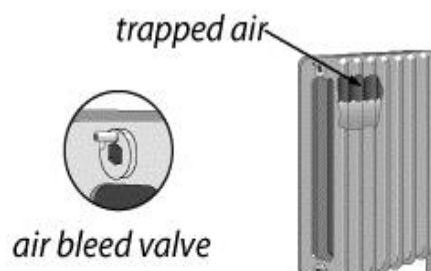
3. If rust is observed in the venting, verify return water temperature is above 130° F for gas and above 150° F for oil, to prevent acidic condensation.
4. Verify the system does not cycle on high limit.
5. Lubricate circulator pump(s) if necessary.



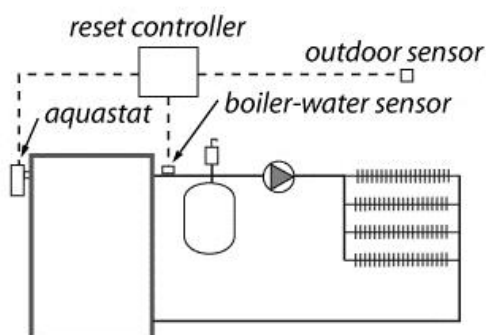
Expansion tank, air separator, and vent: Preventing excessive pressure and eliminating air from the systems are important for hydronic distribution systems.

Efficiency Improvements

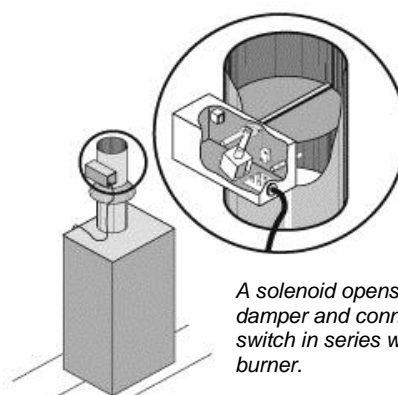
1. Repair water leaks in the system.
2. Remove corrosion, dust, and dirt on the fireside of the heat exchanger.
3. Check for excess air during combustion from air leaks and incorrect fuel-air mixture.
4. Confirm the boiler does not have low-limit control for maintaining a minimum boiler-water temperature, unless the boiler is heating domestic water in addition to space heating.
5. Bleed air from radiators and piping through air vents on piping or radiators.
6. Consider installing outdoor reset controllers on non-high efficiency boilers to regulate water temperature, depending on outdoor temperature.
7. After control improvements like two-stage thermostats or reset controllers, verify return-water temperature is high enough to prevent condensation and corrosion in the chimneys noted previously.
8. Vacuum and clean fins of fin-tube convectors if dust and dirt is present.
9. Consider installing full-closure electric vent dampers on natural-draft gas- and oil-fired high-mass boilers.



Purging air: Trapped air collects at the hot-water system's highest parts. Bleeding air from radiators fills the radiator and gives it more heating surface area.



Reset controller: The circulating-water temperature is controlled by the reset controller according to the outdoor temperature.



Vent dampers: Electric vent dampers close the chimney when the burner isn't firing, preventing circulating air from carrying the boiler's stored heat up the chimney.

3.8 Gas-Fired Heating Systems

3.8.1 Gas-Fired Heating-System Installation

The general procedures outlined in *General Heating-System Replacement in Chapter 3 – Section 3.2*, should be followed. Complete all tests on the Replacement Gas Furnace Check List and document results.

When replacing a gas-fired heating system:

1. Confirm the clearances to nearby combustibles of the heating unit and its vent connector conform to NFPA 54.
2. Clock the gas meter if necessary to troubleshoot oxygen, flue-gas temperature, carbon monoxide, or temperature-rise problems, and to verify the actual gas input matches with the nameplate input rating. Adjust gas input if necessary. See *Measuring BTU Input on Natural-Gas Appliances in Chapter 3 – Section 3.8.3*.
3. Check the input gas pressure on the furnace when all gas-fired appliances are operating in the house to ensure no drop-off in required gas pressure. If the input is significantly different than the rating on the nameplate, all other variables above can be affected.
4. Measure manifold gas pressure to ensure it stays within the manufacturer's specified range. Adjust the fuel-air mixture for the lowest CO output and maximum SSE.
5. Follow manufacturer's venting instructions, along with the NFPA 54 to establish a proper venting system.
6. Follow manufacturer's instructions for proper removal of condensate. See *Condensate Removal in Chapter 3 – Section 3.8.2*.
7. Install a proper sediment trap on the gas line, if none exists.
8. When fuel switching from oil to gas, place the old oil tank out of service in accordance with Wisconsin Administrative Code ATCP 93.315.

3.8.2 Condensate Removal

Condensate is routed away from the furnace in one of two ways:

1. Running condensate tubing or piping directly from the furnace to an appropriate drain (Preferred Method); or
2. Pumping the condensate from the furnace to an appropriate drain using an electric **condensate pump**.

Whenever feasible, pipe directly from the furnace to the floor drain, without installing a condensate pump. Mechanically fasten the piping, either to the floor-drain strainer or to the floor itself. Ensure the piping will not pose a tripping hazard to the occupants. Installing a "trip strip," with the customer's approval, may be useful to prevent occupants from tripping over the piping.

Sometimes, a direct-piping strategy will not be feasible. There may not be a drain near the furnace, or perhaps the piping would pose a tripping hazard to the occupants. In these situations, installing a condensate pump is likely a better option. See the next section for information about condensate pumps.

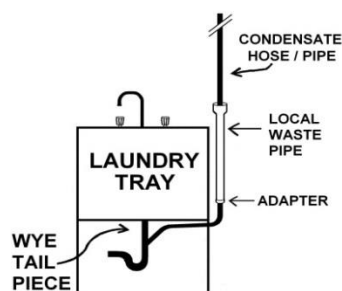
Condensate Pumps

A condensate pump is installed when direct piping to an approved drain is not feasible. Condensate pumps may be installed using existing receptacles, new ground-fault circuit interrupter (GFCI) receptacles, or directly wired in accordance with pump manufacturer's requirements. Inspect the entire condensate system for leaks after installation. Insulate the condensate drain system when it is located in an unconditioned area or has the potential to form condensation. If a condensate pump is installed in a finished area, a secondary drain pan should be installed with a safety feature to disable the heating system if the pump fails. Condensate is a slightly acidic byproduct of combustion. Plumbing code requires it to be drained to the sanitary sewer system, and not to the ground or to a sump pump. Code allows condensate to go to a floor drain, a stand pipe, or an indirect or local waste pipe served by a stand pipe or the laundry tray tail piece. An air gap is required where the condensate line enters the receptor. The condensate line cannot go directly into any drainpipe. See SPS 382.33 for Wisconsin code provisions regarding condensate drains.

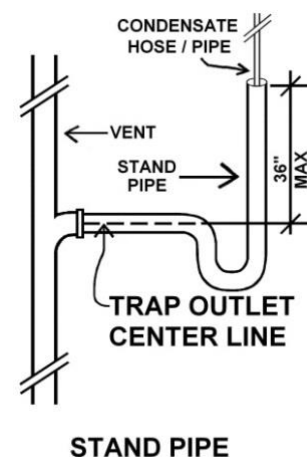
Floor drain: The floor drain is the most common method for discharging condensate. Condensate lines that run to the drain must be secured to the floor to keep them in place. This method works best when the drain is not in a typical path of foot traffic.



Stand pipe: The laundry stand pipe is often the best place to discharge condensate. If the opening is not large enough for the washing machine hose and the condensate line, an adapter can be added to enlarge the top of the pipe. A stand pipe cannot exceed 36 inches in height above the centerline of the horizontal drainpipe. If an existing standpipe is not an option, a new stand pipe, trapped and vented, is acceptable. This option should be the last choice, as the



trap can dry out if the heating system does not discharge condensate over an extended time. If a washing machine could be discharged into the stand pipe, extend the standpipe at least 18 inches above the centerline of the horizontal drainpipe.



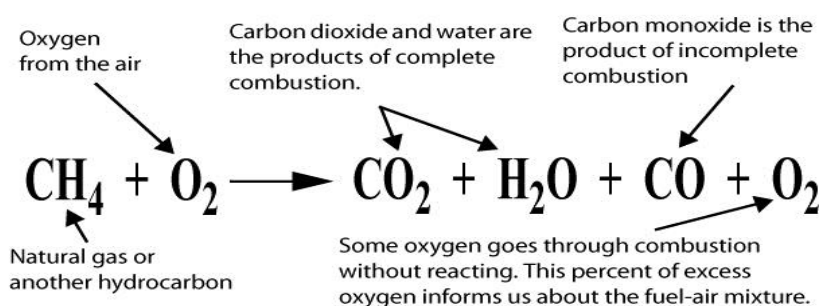
Indirect or local wastepipe: A vertical pipe that uses the trap of a stand pipe or laundry tailpiece is considered an indirect or local

wastepipe. It needs to be higher than the flood line of the laundry tray or stand pipe. This method can also be used if the existing standpipe is full of other hoses.

3.8.3 Testing and Servicing Gas-Fired Systems

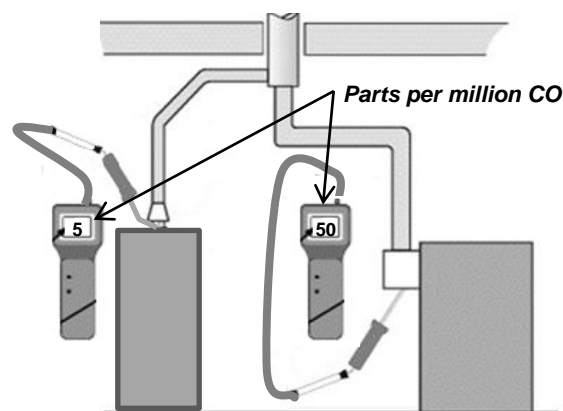
Gas burners should be cleaned and tuned every two to four years. Sometimes a maintenance schedule will be posted on an existing heating system, allowing assessment of the heating-system maintenance history (or lack thereof).

The goals of these service measures are to reduce CO, to optimize fuel-air mixture, and to confirm the operation of safety controls. Complete all tests on the Heating System Repair or Clean and Tune Check List and document results.



Perform the following inspection and maintenance procedures, as necessary, on gas-fired furnaces, boilers, water heaters, and space heaters:

1. Inspect for soot, melted wire insulation, melted grommets, and rust in the burner and manifold area outside the firebox. These all are indicators of flame rollout, combustion-gas spillage, and CO production.
2. Inspect the burners for dust, debris, misalignment, flame impingement, and other flame-interference problems. Clean, vacuum, and adjust as needed.
3. Inspect the heat exchanger for leaks.
4. Verify heating system wiring connections are enclosed in covered electrical boxes.
5. Determine the pilot is burning (if equipped) and main burner ignition is satisfactory.
6. Sample the undiluted combustion gases with a calibrated flue-gas analyzer and record steady-state efficiency, O₂ percentage, CO ppm (as-measured), and flue-gas temperature.



Sampling combustion gases: Sample combustion gases at the exhaust vent of the appliance before dilution air mixes with the gases.



Testing older furnaces: Insert the probe into the draft diverter near the exhaust ports of the heat exchanger.

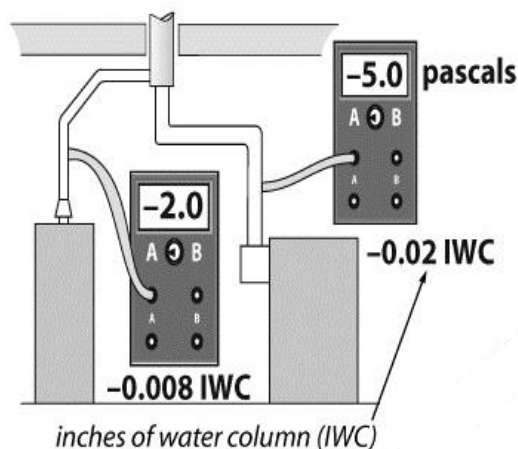


Testing 80+ furnaces: Drill a quarter-inch hole in the metal vent connector to sample combustion gases.

7. Clock the natural-gas meter, with all other gas appliances off, to confirm the input BTUs to the furnace or boiler match with the nameplate rating. Adjust gas pressure if necessary. See *Measuring BTU Input on Natural Gas Appliances in Chapter 3 – Section 3.8.3* for clocking the meter.
8. Clean the air handler (“squirrel cage”) and the air-handler cabinet. Adjust the air handler’s speed setting, if necessary, to ensure adequate airflow and to ensure temperature rise is within the manufacturer’s specifications.
9. Test pilot-safety control for complete gas-valve shutoff when pilot is extinguished.
10. When testing is complete, seal all test holes.
11. Verify the thermostat’s heat-anticipator setting matches the measured current in the 24-volt control circuit.
12. Check venting system for proper size and pitch.
13. Check venting system for obstructions, blockages, or leaks.
14. Measure chimney draft downstream of the draft diverter and check for spillage.
15. Measure gas input, and observe flame characteristics if soot, CO, or other combustion problems are present.



Adjusting gas pressure: Adjusting gas pressure is the only way to change the fuel-air mixture.



Measuring draft: Measuring chimney draft downstream from the draft diverter.

A common furnace-efficiency problem is low fuel input and high O₂ percentage, resulting in poor heat transfer. This condition will be detected by combustion testing and clocking the natural-gas meter. See the standards for O₂ percentage and flue-gas temperature in *Table 3-2*.

Flue-gas temperature is another important indicator of furnace performance. A low flue-gas temperature usually indicates efficient performance, since less of the heat is leaving the building. If the flue-gas temperature is too low in older furnaces or 80+ furnaces; however, acidic condensation will form in the vent. This acidic condensation can rust metal vents and damage masonry chimneys.

Adjust gas pressure and airflow in order to optimize gas input, O₂ percentage, flue-gas temperature, and SSE. These adjustments are best made while monitoring the exhaust gas with the combustion analyzer.

Table 3-2: Typical Ranges for Gas Burning Appliances

Performance Indicator	SSE 80+	SSE 90+
Carbon monoxide (CO) (ppm)	≤ 100	≤ 100
Stack temperature (°F)	325° - 450°	90° - 120°
Temperature rise (°F)	40° - 70°	30° - 70°
Oxygen (O ₂)	4-9%	4-9%
Gas pressure output at manifold - Inches of Water Column (IWC)	3.2 – 3.9	3.2 – 3.9
Propane pressure output at manifold (IWC)	10 – 11	10 – 11
Steady state efficiency (SSE)	82 – 86%	92 – 97%
Supply temperature (°F)	120° - 140°	95° - 140°

Proceed with burner maintenance and adjustment when any of the following are present:

1. CO is greater than 100 ppm as measured or 200 ppm air-free
2. Visual indicators of soot or flame roll-out exist
3. Burners are visibly dirty

Troubleshooting CO

CO >100 ppm Found in One Chamber

1. Open the primary air shutter of the burner where CO is above acceptable limits.
2. Clean that burner and/or pilot assemblies.
3. Align the burner and/or pilot assembly to eliminate impingement
4. Check orifice size and alignment.
5. Check for flame movement and cracks in the heat exchanger.

CO >100 ppm Found in Two Chambers

1. Confirm combustion air source.
2. Check venting system and heat exchanger for blockages.
3. Open primary air shutter on each burner.
4. Clean burners and/or pilot assembly
5. Check orifice size and gas pressure.
6. Measure the appliance input and adjust if necessary.

Carbon Build-up in Heat Exchanger

1. Clean out carbon build-up.
2. Clean all other combustion surfaces including burners, pilot assembly, orifice, and baffles.
3. Inspect heat exchanger for cracks.
4. Reassemble the furnace:
 - a. Set primary air openings.
 - b. Check gas pressure and orifice size.
 - c. Align, position, and level burners.
5. Check venting system and heat exchanger for blockages.
6. Measure the appliance input and adjust if necessary.

Procedures Fail to Reduce CO Below 100 ppm

Re-check the Following Upon:

1. Primary air adjustment.
2. Burner level, alignment, and position.
3. Combustion air source.
4. Gas pressure is correct for type of fuel.
5. Appliance input is altitude adjusted.
6. Venting system is free of obstructions.
7. Heat exchanger is intact.
8. No flame impingement present

Table 3-3: Combustion Problems and Possible Solutions

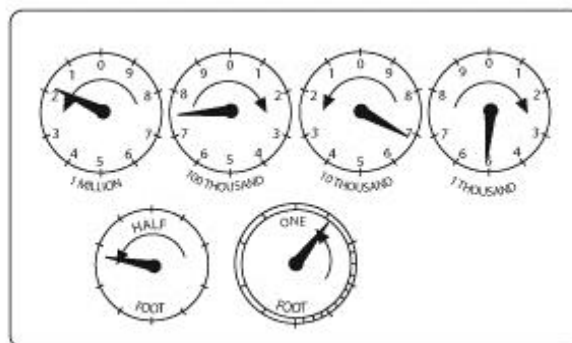
Problem	Possible Causes and Solutions
Weak draft with CAZ depressurization	Return duct leaks, clothes dryer, exhaust fans, other chimneys. Seal return leaks. Provide make-up air.
Weak draft with no CAZ depressurization	Chimney blocked or leaky or else CAZ are too airtight.
Carbon monoxide	Mixture too rich or too lean. Adjust gas pressure. Check chimney and combustion air for code compliance.
Stack temperature or temperature rise too high or low	Adjust fan speed or gas pressure. Improve ducts to increase airflow.
Oxygen too high or low	Adjust gas pressure, but don't increase CO level.

Gas-burner maintenance includes the following measures:

1. Remedy the causes of CO and soot. These causes may include over-firing, closed primary air intake, flame impingement, and lack of combustion air.
2. Remove dirt, rust, and other debris that may be interfering with the burners. Clean the heat exchanger, if necessary.
3. Take action to improve draft, if inadequate because of improper venting, obstructed chimney, leaky chimney, or depressurization. See *Improving Inadequate Draft in Chapter 3 – Section 3.13.1*.
4. Seal leaks in vent connectors and chimneys.
5. Adjust gas input if combustion testing or clocking the gas meter indicates over-firing or under-firing.

Measuring BTU Input on Natural-Gas Appliances

1. Turn off gas supply to all gas-combustion appliances not being tested (such as heating systems, water heaters, dryers, cook stoves, space heaters, etc.) that are connected to the meter being timed.
2. Fire the appliance being tested, and watch the dials of the gas meter.
3. Carefully count how long it takes for one revolution of the $\frac{1}{2}$ -, 1-, or



Gas meter dial: Use the number of seconds per revolution of the one-foot dial and the table on the following page to find the appliance's input.

2-cubic-foot dial. Find that number of seconds in the columns marked “Seconds per Revolution” in *Table 3-4*. Follow that row across to the right to the correct column for the $\frac{1}{2}$ -, 1-, or 2-cubic foot dial. Multiply the number in the table by 1000. Record the input in thousands of BTUs per hour. *For gauging a $\frac{1}{4}$ -cubic-foot dial, count how long it takes for 4 revolutions. Then, use the 1-cubic-foot column to determine the input.*

4. If the measured input is higher or lower than input on the nameplate by more than 10 percent, adjust gas pressure up or down, within the ranges in *Table 3-3*, until the approximately correct input is achieved. **CAUTION:** Consult with fuel supplier before adjusting pressure at meter.
5. For LP gas, determine the orifice size. From Table E.1.1 of the National Fuel Gas Code, find the input BTU value that corresponds with the orifice size. Multiply the listed BTU value by the number of orifices to get the input BTU for the heating system.
6. If the measured input is still out of range after adjusting gas pressure to these limits, replace the existing orifices with larger or smaller orifices sized to give the correct input. Any changes done to orifices must follow manufacturer’s instructions.

Table 3-4: Input in Thousands of Btu/hr for 1000 Btu/cu. ft. Gas

Seconds per Revolution	Size of Meter Dial			Seconds per Revolution	Size of Meter Dial			Seconds per Revolution	Size of Meter Dial		
	½ cu. ft.	1 cu. ft.	2 cu. ft.		½ cu. ft.	1 cu. ft.	2 cu. ft.		½ cu. ft.	1 cu. ft.	2 cu. ft.
15	120	240	480	40	45	90	180	70	26	51	103
16	112	225	450	41	44	88	176	72	25	50	100
17	106	212	424	42	43	86	172	74	24	48	97
18	100	200	400	43	42	84	167	76	24	47	95
19	95	189	379	44	41	82	164	78	23	46	92
20	90	180	360	45	40	80	160	80	22	45	90
21	86	171	343	46	39	78	157	82	22	44	88
22	82	164	327	47	38	77	153	84	21	43	86
23	78	157	313	48	37	75	150	86	21	42	84
24	75	150	300	49	37	73	147	88	20	41	82
25	72	144	288	50	36	72	144	90	20	40	80
26	69	138	277	51	35	71	141	94	19	38	76
27	67	133	267	52	35	69	138	98	18	37	74
28	64	129	257	53	34	68	136	100	18	36	72
29	62	124	248	54	33	67	133	104	17	35	69
30	60	120	240	55	33	65	131	108	17	33	67
31	58	116	232	56	32	64	129	112	16	32	64
32	56	113	225	57	32	63	126	116	15	31	62
33	55	109	218	58	31	62	124	120	15	30	60
34	53	106	212	59	30	61	122	130	14	28	55
35	51	103	206	60	30	60	120	140	13	26	51
36	50	100	200	62	29	58	116	150	12	24	48
37	49	97	195	64	29	56	112	160	11	22	45
38	47	95	189	66	29	54	109	170	11	21	42
39	46	92	185	68	28	53	106	180	10	20	40

3.8.4 Leak-Testing Gas Piping

For information on leak-testing gas piping, see *Leak-Testing Gas Piping in Chapter 5 – Section 5.4.5*.

3.9 Oil-Fired Heating Systems

3.9.1 Oil-Fired Heating-System Installation

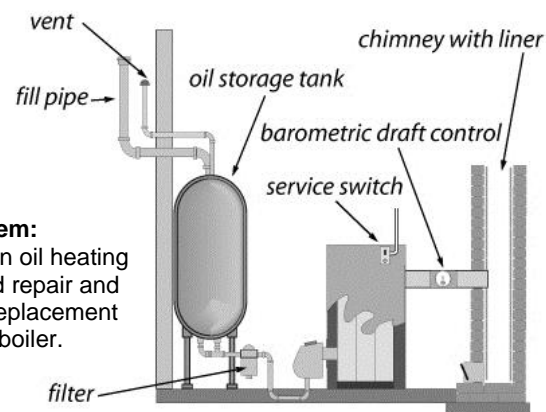
The general procedures outlined in *General Heating System Replacement in Chapter 3 - Section 3.2* should be followed when replacing an oil heating system. Complete all tests on the Oil Replacement Furnace Check List and document results.

When replacing an oil furnace:

1. Properly size the nozzle based on the post-weatherization conditions, using REScheck®, Manual J, or an equivalent industry-accepted sizing formula. Document the nozzle size on the inside of the furnace cabinet, next to the furnace nameplate.
2. Examine the existing chimney and vent connector for suitability as venting for the new appliance. The vent connector may need to be resized, and the chimney may need to be relined.
3. Confirm the clearances to nearby combustibles of the heating unit and its vent connector conform to NFPA 31.
4. Test oil pressure, and verify it complies with the manufacturer's specifications.
5. Test control circuit amperage and adjust the thermostat's heat anticipator to match.
6. Test smoke number to confirm it meets manufacturer's specifications. See *Table 3-5*. Install a new fuel filter, and purge the fuel lines.
7. Verify the chimney operates safely and in accordance with NFPA 211.
8. Confirm the tank and oil lines comply with NFPA 31.

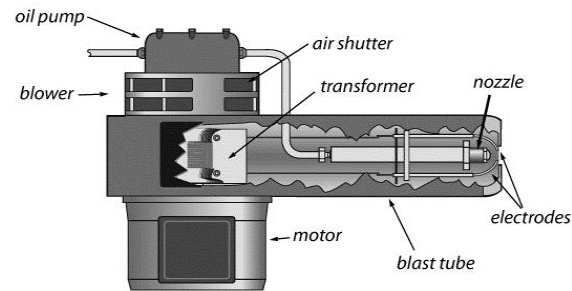
Oil heating system:

Components of an oil heating system may need repair and cleaning during replacement of the furnace or boiler.



3.9.2 Testing and Servicing Oil-Fired Systems

Oil burners require annual maintenance to retain their operational safety and combustion efficiency. Testing for steady-state efficiency, draft, carbon monoxide, and smoke should be used to guide and evaluate maintenance. These clean-and-tune procedures pertain to oil-fired furnaces, boilers, and water heaters.



Oil burner operation: For continual and complete burning of the oil, oil is pumped through the nozzle to create a specific spray pattern that is ignited by properly spaced electrodes carrying 10,000 volts from the transformer.

Oil-Burner Inspection and Testing

Evaluate oil-burner operation by visually inspecting and combustion testing the system. An oil burner passing visual inspection and giving good test results may need minimal maintenance. If the test results are fair, adjustments may be necessary. Unsatisfactory test results may indicate the need to replace the burner or the entire heating unit.

Follow these steps to improve oil-burner safety and efficiency:

1. Inspect burner and appliance for signs of soot, overheating, fire hazards, corrosion, or wiring problems.
2. Equip all oil-fired heating systems with a barometric draft control.
3. Confirm the oil heating system has a dedicated electrical circuit.
4. Enclose all 120-volt wiring connections in covered electrical boxes.
5. Inspect fuel lines and storage tanks for leaks.
6. Inspect the heat exchanger and combustion chamber for cracks, corrosion, or soot buildup.
7. Check to see if the flame ignition is instantaneous or delayed. The flame ignition should be instantaneous, except for pre-purge units where the blower runs for a while before ignition.
8. Sample undiluted flue gases with a smoke tester, following the smoke-tester instructions. Compare the smoke smudge left by the gases on the filter paper with the manufacturer's smoke-spot scale to determine smoke number. *With a smoke number of two or higher, do not use the electronic combustion analyzer.*
9. Analyze the flue gas for O₂ percentage, temperature, CO ppm, and steady-state efficiency (SSE). Sample undiluted flue gases between the barometric draft control and the appliance. Adjust fuel-air mixture and airflow to conform to standards in *Table 3-5*.

10. Measure flue draft between the appliance and barometric draft control and over-fire draft at an opening to the firebox.

11. Measure high-limit shut-off temperature, and adjust or replace the high-limit control if the shut-off temperature is more than 200° F for furnaces or 180° F for hot-water boilers.

12. Measure the oil-pump pressure, and adjust to manufacturer's specifications if necessary.

13. Measure transformer voltage, and replace transformer if not within the allowable range.

14. Ensure barometric draft controls are mounted plumb and level, and the damper swings freely.

15. Time the CAD cell control or stack control to verify that the burner will shut off, within the time frame per manufacturer's specifications, when the CAD cell is blocked from seeing the flame.

Table 3-5: Typical Ranges for Oil Burning Appliances

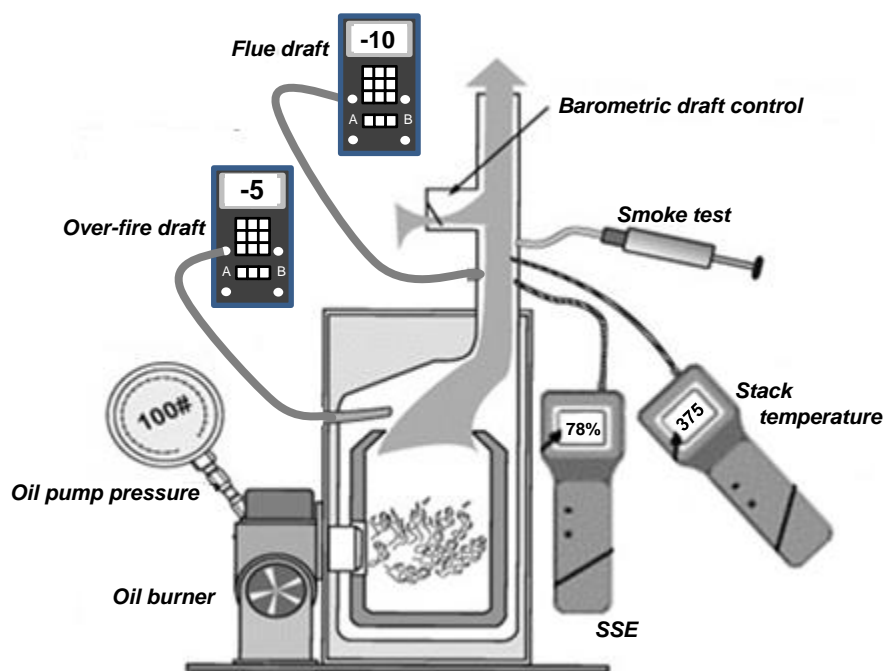
Performance Indicator	Non-Flame Retention	Flame Retention
Carbon monoxide (CO) (ppm)	≤ 100	≤ 100
Stack temperature (°F)	325° - 550°	300° - 450°
Oxygen (O ₂)	6-9%	5-9%
Smoke number (1-9)	≤ 2	≤ 1
Excess air (%)	≥ 80%	≥ 35%
Oil pressure pounds per square inch (psi)	≥ 100	100 -150
Over-fire draft (Inches of Water Column - IWC negative)	.02 IWC or 5 Pa	.02 IWC or 5 Pa
Flue draft (IWC negative)	.04 -.01 IWC or 10-15 Pascals	.04 -.01 IWC or 10-15 Pascals
Steady state efficiency (SSE)	≥ 75%	≥ 80%

Oil-Burner Maintenance and Adjustment

After evaluating the oil burner's initial operation, perform the following maintenance tasks as needed to optimize safety and efficiency:

1. Verify correct flame-sensor operation.
2. Replace the burner nozzle after matching the new nozzle's size to the home's post-weatherization heat-load requirements.
3. Clean the burner's blower wheel.
4. Replace oil filter(s).
5. Clean or replace air filter. See *Filters in Section 3.4.6* for guidance on providing furnace filters.
6. Remove soot and sludge from combustion chamber.
7. Remove soot from heat-exchange surfaces.

8. Clean dust, dirt, and grease from the burner assembly.
9. Ensure the oil pump is set to the correct pressure.
10. Adjust barometric damper for a negative over fire draft of 5 Pascals or 0.02 IWC, per manufacturer's specifications.
11. Adjust gap between electrodes and their position in burner tube, per manufacturer's specifications.
12. Repair the ceramic combustion chamber, or replace it if necessary.
13. Inspect and clean the end of the burner-tube assembly. Replace flame-retention head if damaged.
14. Inspect and clean the transformer contacts to remove any corrosion.
15. Adjust air shutter to achieve O₂ and smoke values, specified in *Table 3-5*.



Measuring oil-burner performance: To measure oil-burning performance indicators, a manometer, flue-gas analyzer, smoke tester, and pressure gauge are required.

After these maintenance procedures, perform the diagnostic tests described previously to evaluate improvement made by the maintenance procedures and to determine if fine-tuning is required.

3.10 Electric Furnaces and Electric Baseboard Heat

In Wisconsin, electric baseboard heat is much more common than electric furnaces. Due to the high cost of electricity, these systems may be good candidates for fuel switching.

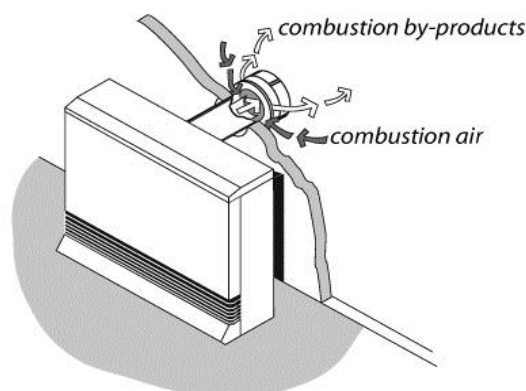
Caution: Disconnect power from electric furnaces before performing any maintenance.

1. Check or clean and lubricate the following components: thermostat, blower, housing around electric element, and baseboard fins.
2. Clean or replace all filters.
3. Take extra care in duct sealing and in duct-airflow improvements for electric furnaces because of the high cost of electricity.
4. Verify safety limits and temperature rise conform to manufacturer's specifications.

3.11 Replacing Space Heaters

When replacing a space heater:

1. Follow the manufacturer's venting instructions carefully. Do not vent sealed-combustion, induced-draft space heaters into naturally drafting chimneys.
2. If the space heater will sit on a carpeted floor, provide a fire-rated floor protector, sized to the width and length of the space heater, as a base.
3. Locate space heater away from traffic, draperies, and furniture.
4. Space heaters require a properly grounded duplex receptacle for electrical service.



Sealed combustion space heater: A sealed combustion space heater draws combustion air in and exhausts combustion by-products using a draft fan.

Inform the customer of the following operating instructions:

1. Do not store any objects near the space heater that would restrict airflow around it.
2. Do not use the space heater to dry clothes or for any purpose other than heating the home.
3. Do not allow anyone to lean or sit on the space heater.
4. Do not spray aerosols near the space heater. Many aerosols are flammable or can cause corrosion to the space heater's heat exchanger.



Space heater controls: Many modern energy-efficient space heaters have programmable thermostats as standard features.

3.12 Replacing Wood Stoves

Wood stoves with a crack or hole in the firebox should be replaced. Units that do not meet clearances and cannot be corrected should be considered for replacement. All replacement wood stoves must meet applicable local codes and EPA requirements. Installations must conform to the NFPA 211.

When replacing a wood stove:

1. Install the stove to meet manufacturer's specifications.
2. Verify the replacement stove is certified to meet EPA emission standards or local standards, whichever are stricter.
3. Confirm the installed unit is certified and labeled by:
 - a. National Fire Protection Association under 211-1996
 - b. Other equivalent listing organization
4. Visually inspect the chimney for safe operation by referring to NFPA 211.
5. Provide all customers with in-home operation instructions, to include proper wood-burning practices; safety information; and education about proper maintenance, such as stack thermometers and the need for fire extinguishers.
6. Educate the customers about the potential impact of exhaust ventilation and/or forced-air distribution on the wood heater's operation.

Install make-up air if the building is tightened below the Depressurization Limit CFM₅₀.

3.13 Venting Combustion Gases

Proper venting is essential to the operation, efficiency, safety, and durability of combustion heaters. The National Fire Protection Association (NFPA) and the International Code Council (ICC) are the authorities on material-choice, sizing, and clearances for chimneys and vent connectors, as well as for combustion air. The information in this venting section is based on the following NFPA and ICC documents:

- ✓ The International Fuel Gas Code (IFGC) (ICC)
- ✓ NFPA 31: Standard for the Installation of Oil-Burning Equipment
- ✓ NFPA 211: Standard for Chimneys, Fireplaces, Vents, and Solid-Fuel- Burning Appliances

Table 3-6: Guide to Venting Standards

Topic	Code Reference
Venting sizing	IFGC, Section 504
Clearances	IFGC, Section 308 and Tables 308.21 NFPA 31, Section 4-4.1.1 and Tables 4-4.1.1 and 4-4.1.2 NFPA 211, Sections 6.5, 4.3, 5
Combustion air	IFGC, Section 304 NFPA 31, Section 1-9; NFPA 211, Section 8.5 and 9.3

3.13.1 Improving Inadequate Draft

If measured draft is below the minimum worst-case requirement, investigate the reason for the weak draft. Open a window, exterior door, or interior door that is below the level of the heating appliance to observe whether the addition of make-up air will improve draft. If the added air strengthens draft, then the problem is usually depressurization. If opening a window has no effect, inspect the chimney. The chimney could be blocked or excessively leaky.

Chimney Improvements to Solve Draft Problems

Consider the following chimney improvements when attempting to improve worst-case draft:

1. Remove chimney obstructions.
2. Repair disconnections or leaks at joints and where the vent connector joins a masonry chimney.
3. Measure the size of the vent connector and chimney and compare with vent-sizing information listed in Section 504 of the International Fuel Gas Code. A vent connector or chimney liner, either too large or too small, can result in poor draft.
4. Increase the pitch of horizontal sections of vent, to facilitate the flue gases' movement toward the chimney.
5. Extend the flue's roof-jack. This option may be especially useful when the appliance's exhaust stack is short — for example, in a mobile home, or in a ranch home on a slab.
6. If wind is causing erratic draft, consider installing a wind-dampening chimney cap.

If the masonry chimney is deteriorated, consider installing a new chimney liner.

Duct Improvements to Solve Draft Problems

Consider the following duct and airflow improvements when attempt to improve worst-case draft:

1. Seal/remove any return grilles in the CAZ.

2. Install a sealing filter cover.
3. Seal return-duct leaks in the CAZ, using the diagnostic workbook to guide duct-sealing decision-making.
4. Isolate the furnace from its return registers by air sealing.
5. Install make-up air to the CAZ. Open a nearby window, exterior door, or interior door to observe whether the addition of make-up air will improve draft. If the open window or door improves draft to an acceptable level, measure the size of the opening, and install make-up air accordingly.

Table 3-7: Draft Problems and Solutions

Problem	Possible Solutions
Adequate draft never established	Remove chimney blockage, seal chimney air leaks, or provide additional combustion air as necessary.
Blower activation weakens draft	Seal leaks in the furnace and in nearby return ducts. Isolate the furnace from nearby return registers.
Exhaust fans weakens draft	Provide make-up or combustion air if opening a door or window to outdoors strengthens draft during testing.
Closing interior doors during blower operation weakens draft	Add return ducts, grills between rooms, or jumper ducts.

3.14 Combustion Air

A combustion-appliance zone is classified as either an **unconfined space** or as a **confined space as defined by the IFGC**. An unconfined space is a CAZ connected to enough building air leakage to provide combustion air. A confined space is a CAZ with sheeted walls and ceiling and a closed door that form an air barrier between the appliance and other indoor spaces.

For confined spaces, the IFGC prescribes additional combustion air from outside the CAZ. Combustion air is supplied to the combustion-appliance zone in four ways.

1. To an unconfined space through leaks within the building
2. To a confined space through an intentional opening or openings between the CAZ and other indoor areas where air transfers in to replenish combustion air
3. To a confined space through an intentional opening or openings between the CAZ and outdoors or ventilated intermediate zones like attics and crawl spaces
4. Directly from the outdoors to the confined or airtight CAZ through a duct. Appliances with their own direct combustion-air ducts are called **sealed-combustion** or **direct-vent** appliances.

Table 3-8: CFM Air Requirements for Combustion Furnaces or Boilers

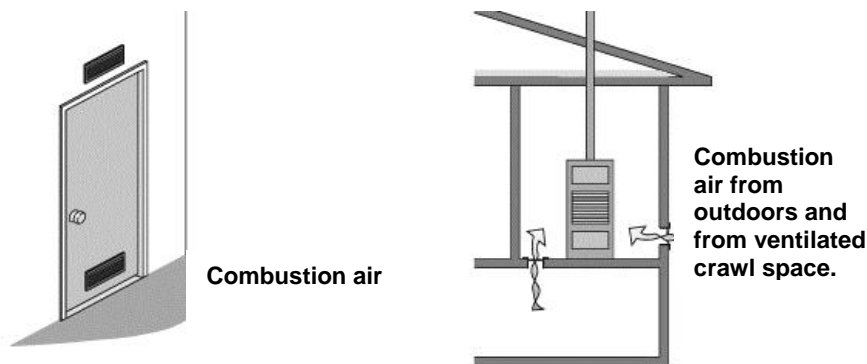
Appliance	Combustion Air (CFM)	Dilution Air (CFM)
Conventional Oil	38	195
Flame-Retention Oil	25	195
High-Efficiency Oil	22	-
Conventional Atmospheric Gas	30	143
Fan-Assisted Gas	26	-
Condensing Gas	17	-
Fireplace (no doors)	100-600	-
Airtight Wood Stove	10-50	-
A.C.S. Hayden, Residential Combustion Appliances: Venting and Indoor Air Quality Solid Fuels Encyclopedia		

3.14.1 Unconfined-Space Combustion Air

Combustion appliances located in most basements, attics, and crawl spaces get adequate combustion air from leaks in the building shell. Even when a combustion appliance is located within the home's living space, it usually gets adequate combustion air from air leaks, unless the house is airtight or the combustion zone is depressurized.

3.14.2 Confined-Space Combustion Air

A confined space is defined by the IFGC as a room containing one or more combustion appliances and which has less than 50 cubic feet of volume for every 1,000 BTUs per hour (BTUH) of appliance input.



Passive combustion-air options: Combustion air can be supplied from adjacent indoor spaces or from outdoors. Beware of passive combustion-air vents into the attic that could depressurize and combustion zone or allow moist air to travel into the attic.

If a small mechanical room is connected to adjacent spaces through large air passages like floor-joist spaces, however, the CAZ may not need additional combustion air, even with sheeted walls and a door separating it from other indoor spaces. The extent of the connection between the CAZ and other spaces can be confirmed by worst-case draft testing or blower-door testing.

On the other hand, if the home is unusually airtight, the CAZ may not be able to obtain adequate combustion air, even when the CAZ is larger than the minimum confined-space room volume, defined above.

In confined spaces or airtight homes where outdoor combustion air is needed, the best strategy is a single-vent opening installed as low in the CAZ as is practical. A combustion-air vent into an attic may depressurize the combustion zone or dump warm, moist air into the attic. Instead, connect the combustion zone directly to the outdoors or to a ventilated crawl space through a single low vent, if possible.

Choose an outdoor location that is sheltered, where the wall containing the vent is not parallel to prevailing winds. Wind blowing parallel to an exterior wall or at a right angle to the vent opening tends to de-pressurize both the opening and the CAZ connected to it. Indoors, locate combustion air vents away from water pipes to prevent the pipes from freezing.

3.14.3 Net-Free Area

Net-free area is the surface area of venting that remains open after subtracting for the blocking effect of louvers and grilles. Metal grilles and louvers are assumed to reduce the size of the vent opening to 75 percent of the original surface area. Wooden grilles and louvers are more restrictive, and they are assumed to reduce the net free area to 25 percent of the original surface area.

Manufacturers often provide specifications about the net-free area through their grilles and louvers. When this information is available, use it to calculate the size of opening required to provide the net free area necessary. When these specifications are not available, use the assumptions listed above.

For example, calculate a 10 inch by 10-inch opening (100 square inches) with a metal grille attached as having 75 square inches of net free area. With a wooden louver installed, to calculate the same opening use 25 square inches of net-free area.

When sizing vent openings, always account for the reduction in the net-free area that will occur due to the installation of grilles and louvers.

3.14.4 Sizing Combustion-Air Openings

Table 3-9 summarizes the required ratios of combustion-air net free area to appliance input (BTUH).

Here is an example of sizing two direct combustion-air openings to adjacent indoor space: The furnace and water heater are located in a confined space. The furnace has an input rating of 100,000 BTUH. The water heater has an input rating of 50,000 BTUH. Combined, the two appliances have an input rating of 150,000 BTUH. Therefore, each opening must have at least 150 square inches of net free area of venting between the mechanical room and adjacent indoor space ($150,000 \div 1,000 = 150$). There are two openings, so the CAZ will have a total of 300 square inches of net-free area of venting.

If the same CAZ were ducted to the outdoors with a single opening, the requirement for the net-free area of venting would decrease to 50 square inches ($150,000 \div 3,000 = 50$ sq. in.).

When installing two combustion-air openings, the IFGC usually requires one opening commences 12 inches from the ceiling and one opening 12 inches from the floor. See IFGC 2012, Section 304.5 for a full breakdown of combustion-air requirements.

Table 3-9: Combustion Air Openings: Location and Size

Location	Dimensions
Two direct openings to adjacent indoor space	Minimum area each: 100 in^2 1 in^2 per 1000 BTUH each combined rooms volumes must be $\geq 50 \text{ ft}^3$ per 1000 BTUH
Two direct openings or vertical ducts to outdoors	Each vent should have 1 in^2 for each 4,000 BTUH
Two horizontal ducts to outdoors	Each vent should have 1 in^2 for each 2,000 BTUH
Single direct or ducted vent to outdoors	Single vent should have 1 in^2 for each 3,000 BTUH
From the <i>International Fuel Gas Code (IFGC)</i> .	

3.15 Thermostats

Set the thermostat's heat anticipator to the amperage measured in the control circuit, or follow the thermostat-manufacturer's instructions for adjusting cycle length.

3.15.1 Programmable Thermostats

A programmable thermostat may be a big energy saver if the occupants understand how to operate the thermostat. If the existing thermostat will be replaced as a part of the weatherization work, discuss this option with the occupant. If the occupant is willing to use a programmable thermostat, proceed with the installation. Educate the occupant on the use of the thermostat, and leave a copy of manufacturer's directions with them.

Final Inspection and Quality Assurance Standards

Heating system work shall meet the following standards.

Required Outcomes		
	Replacements	Clean and Tune
All Fuels and Types	1. The carbon monoxide concentration in the undiluted flue gas does not exceed 100 ppm as-measured or 200 ppm air-free, unless manufacturer's specification limit is higher.	1. The carbon monoxide concentration in the undiluted flue gas does not exceed 100 ppm as-measured or 200 ppm air-free, unless manufacturer's specification limit is higher.
Gas Systems	2. Test and set the gas pressure within the manufacturer's specifications.	2. Test and set the gas pressure within the manufacturer's specifications
Oil Systems	3. The smoke test: ≤ 1 for flame retention burner systems and ≤ 2 for non-flame retention burner systems using a smoke-spot scale	3. The smoke test: ≤ 1 for flame retention burner systems and ≤ 2 for non-flame retention burner systems using a smoke-spot scale.
Forced-Air	4. The temperature rise is within the manufacturer's specification.	4. The temperature rise is within the manufacturer's specification.
All Boilers	5. O ₂ and CO (or CO ₂) values are within manufacturer's specified range. 6. Non-condensing boiler: The stack temperature is at least 300° F to minimize condensation in the chimney.	5. O ₂ and CO (or CO ₂) values are within manufacturer's specified range. 6. Non-condensing boiler: The stack temperature is at least 300° F to minimize condensation in the chimney.
$\geq 90\%$ Boilers	7. Outside air temperature sensor is installed on a north-facing exterior wall. 8. Heating curve is programmed in line with the dwelling's heat loss and radiation capacity.	7. Outside air temperature sensor is installed on a north-facing exterior wall. 8. Heating curve is programmed in line with the dwelling's heat loss and radiation capacity.

Heating Systems – General

1. Heating System Check List is complete, in file;
2. Condensate:
 - a. Properly drains and is secured to floor drain.
 - b. Does not present a tripping hazard.
 - c. Pump installed only when needed.
3. No fuel leaks.
4. Oil systems have a new oil filter.
5. There are no pre-existing unvented space heaters remaining in place.

Required Testing		
	Replacements	Clean and Tune
All Fuels and Types	1. Measure the steady-state efficiency (SSE).	1. Measure the steady-state efficiency (SSE).
	2. Measure oxygen (O ₂) levels. See Table 3-2, Typical Ranges for Gas-Burning Equipment.	2. Measure oxygen (O ₂) levels. See Table 3-2, Typical Ranges for Gas-Burning Equipment.
	3. Measure the stack temperature (T-Stack).	3. Measure the stack temperature (T-Stack).
Forced-Air	4. Measure the airflow of the furnace air handler. Use a flow plate or the manufacturer's fan-flow tables to calculate airflow.	4. Measure the airflow of the furnace air handler. Use a flow plate or the manufacturer's fan-flow tables to calculate airflow.
All Boilers	5. Measure the supply and return water temperatures.	5. Measure the supply and return water temperatures.

New Heating Systems

1. Heating system is properly sized and adequately heats the building.
 - a. Sizing calculation is in the customer file that accurately reflects the heat loss of the post-weatherization building.
 - b. Distribution system is adequate for the properly sized furnace.
2. Heating system has proper venting.
 - a. Meets manufacturer's and code requirements.
 - b. Proper clearances from windows, doors, and 3 feet from a gas meter, regulator, and vent outlet.
3. System is raised off the floor by durable materials.
 - a. For basements with known water problems, the height is based on typical high water marks noted in the CAZ or based on customer input.
4. Heating system equipment meets specification requirements.
5. Building permit obtained as required.
6. Installation meets code requirements.
7. System is on a dedicated electrical circuit.
 - a. Service disconnect is present or within line-of-sight at service panel.
 - b. Circuit is properly sized or a fuse or breaker is installed to protect the system.
8. The warranty and/or manual booklet is posted on or near the furnace.
9. Installed wood systems or stoves comply with NFPA 211 or EPA (per label).

Forced-Air Distribution

1. Filter/compartment
 - a. Is properly sealed, tight cover fit, and the filter seals to the filter rack.
 - b. Allows for easy filter replacement.
 - c. Filter is MERV 6 or better.
 - d. One cleanable filter, six disposable 1- to 2-inch filters included, or one 3-inch filter installed.
2. Distribution within the CAZ and living areas are sealed based on worst-case depressurization testing. The distribution system does not excessively depressurize the CAZ, (>1 Pascal, based on warnings in the diagnostic workbook when Category I appliances are present).
3. Adequate heat and return air is provided in the living areas.

4. New supply and return ducts are the proper size for efficient operation of the heating system.
5. Duct joints are properly attached and secured.
6. Ducts are properly supported.
7. Metal ducts are sealed with a UL181 rated material like mastic, tape or caulk.
8. Distribution work in unheated areas is insulated to minimum of R-11.
9. Insulation meets material specifications and is not compressed.
10. Fiberglass insulation is installed with mechanical fasteners.
11. Registers are properly functioning for their intended purpose.
12. There are no return grills in the CAZ.
13. New supply ducts have dampers.
14. Mobile home return air system is centralized through living space.
15. Back-draft dampers are installed between a wood furnace plenum and another forced air system.

Boilers

1. Boiler size is properly calculated and includes domestic hot water when applicable.
2. Existing radiators and other terminal devices are the appropriate size and quantity for the spaces they heat.
3. Heating System Check List is complete and in file.
4. Replacement units are rated for the application.
5. The existing feed water and distribution system works properly with a new boiler.
6. Distribution system was properly flushed.
7. Boiler controls, auto fill valve, zone valve, and expansion tank are present and functioning as designed and outdoor air temperature sensor is installed.
8. Existing boiler or distribution is adjusted or modified properly.
9. Radiators are bled and there no air is in the system.
10. Pressure relief valve has been documented as opened; closes without leaking.
11. Three- and four-unit buildings only. Boiler registration number is posted with current state certified inspection.

Hot-Water Space-Heating Distribution

1. Pipes are insulated in unheated areas.
2. Insulation seams are tightly fitted and secured.
3. No leaks in the system.

Thermostats

1. Installed thermostat functions properly with the installed heating system and meets household needs.
2. Customer is educated and understands how to operate programmable thermostat.
3. Thermostat is in a location that allows the heating system to operate properly heat the space.
4. Thermostat is installed on an interior wall but not near a supply register.

Additional Considerations

Under certain circumstances, the following items may be necessary to verify other tests results are correct or for troubleshooting various problems.

1. Airflow through the flow meter is consistent with flow rate listed in Table 3-1 and the manufacturer's fan tables.

Additional Tests		
	Replacements	Clean and Tune
All Systems	1. Confirm excess air (EA) is adequate.	1. Confirm excess air (EA) is adequate.
Natural Gas Systems	2. Measure the input by "clocking the meter" to determine the input of a natural gas appliance. Input is typically within 10% of the appliance rating.	2. Measure the input by "clocking the meter" to determine the input of a natural gas appliance. Input is typically within 10% of the appliance rating.
Oil Systems	3. Check oil pump pressure.	3. Check oil pump pressure.
Forced-Air	4. Measure external static pressure (ESP).	4. Measure external static pressure (ESP).